A STUDY OF PHYSICAL INVENTORY METHODOLOGIES FOR THE WRIGHT-PATTERSON AFB MEDICAL CENTER SUPPLY ACTIVITY

THESIS

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Master of Science in Logistics Management

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Preface

This study examines the physical inventory methodology currently employed at the Wright-Patterson Air Force Base Medical Center (WPMC) Supply Activity. The goal of the research is to determine if, by changing the method of conducting physical inventories, cost savings can be realized while customer service levels are maintained.

This study compares the costs and levels of customer service, as measured by the parameters of inventory accuracy and operational disruption, associated with selected physical inventory methodologies. The findings and recommendations of this study are valuable to medical logistics managers within the Department of Defense, particularly those involved in attempts to reduce inventory carrying costs.

This thesis was by no means a two person effort. We are thankful to God for getting us through this process. We also owe a great debt of gratitude to our wives and children for supporting us throughout the AFIT Experience. We are deeply indebted to our thesis advisors, Lieutenant Colonel Rod Rice and Major Karen Currie, for their guidance, patience and professionalism. Finally, we want to thank Lieutenant Colonel Romeyn and the personnel of the WPMC for their assistance, flexibility and willing support.

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Abstract

This study evaluates current and alternative physical inventory methodologies for the Wright-Patterson Medical Center Supply Activity. Four potential physical inventory alternatives were examined: 1) 100 percent annual physical inventory; 2) statistical sampling; 3) continuous cyclic; and 4) stratified cyclic. For each alternative the researchers used historical data and a site survey to estimate the effect on physical inventory costs and impact on customer service. The researchers found that statistical sampling was the most economically feasible alternative for the Wright-Patterson Medical Center. However, the method of stratified cyclic produced less extreme scores in both physiclal inventory cost and customer service parameters than did statistical sampling. The researchers found that further research is needed in the recommended methodologies of statistical sampling and stratified cyclic.

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I. Introduction

General Issue/Background

In late 1993 the Wright-Patterson Air Force Base (WPAFB) Medical Center Supply Activity received new warehousing equipment. The receipt of the new equipment was part of an effort to relocate the supply activity's warehouse from building number 274 to the basement of the Wright-Patterson Medical Center (WPMC). The relocation was completed in May of 1994. The repercussions associated with this relocation are numerous, and require an analysis of operating procedures.

As part of the relocation, the supply activity became the test bed for installation of new warehousing technology Air Force wide. The new technology that the WPMC supply activity's warehouse received was horizontal carousels, mobile aisles, and computer software to operate the equipment and manage the inventory.

In previous years, the WPMC Supply Activity's warehouse was labor intensive and used non-moveable pallet racks for storage with wide aisles to permit access to storage locations. While this method of storage was effective, it was not very efficient, because the size of

the warehouse allowed for inefficiency in processing requisitions. The warehouse was large enough to accommodate storing all items carried in inventory, but did not force the warehouse management to optimize space utilization. The availability of additional space in the old warehouse allowed line items of the same national stock numbers to be stored in the same general locations. The new warehousing technology, or automated storage system, forces a redistribution of inventories. The locations of items are distributed in the bins by item type, as well as, by lot and shelf life date. This redistribution of stock could result in the same item being located in multiple locations in the warehouse, which differs from the previous method of storing like items in the same location. Thus, the manner by which the supply activity conducts its physical inventories needed to be reevaluated based upon the redistribution of stocks and new procedures associated with the automated storage system (Romeyn, 1994).

One of the primary concerns in reevaluating physical inventory procedures is maintaining inventory accuracy. In a hospital environment inventory accuracy is imperative to providing efficient and effective supply accountability of stocks, which is one of the primary concerns of the WPMC supply activity. The mission of the WPMC Supply Activity is to ensure that the medical center's staff has the necessary materiel on hand to care for WPMC patients.

The repercussions associated with the relocation of the warehouse affect how business is currently done. The supply activity's managers have space and equipment constraints imposed upon them. Specifically, these constraints may require more efficient physical inventory methods. The goal of a physical inventory is to prevent stock-outs and detect and identify accounting problems. According to Air Force regulations, "the objective of physical inventories is to verify stock record balances against actual stocks on-hand" (DAF, 1990:12-4). Current Air Force Regulations dictate that these inventories be conducted according to a minimum frequency as follows:

> Either a complete physical count of all property as of a specified date or a total cyclical physical count of selected groups of items scheduled to result in a count of all items during a specified time period must be taken annually. When the accuracy of a complete or a cyclical Federal Supply Class (FSC) inventory is less than 95 percent, that class will be reinventoried within six months; however, this will not exempt the requirement for the regularly scheduled annual inventory. (DAF, 1990:12-4)

The WPMC Supply Activity must adhere to these requirements while their method of storing inventory has changed, and while they explore other methods of performing physical inventories. Conducting physical inventories is costly in terms of manpower and reduced customer service levels. Manpower costs are incurred in the form of extended work hours required to accomplish the inventory within given time

limits. In addition, the requirement to close activities during inventories to ensure accurate counts affects customer service levels. As a result, the WPMC's supply managers have been forced to confront this question: how can the medical center's supply activity ensure uninterrupted quality service while maintaining accountability of stocks and minimizing costs?

Purpose.

To help answer that question, this research examines and analyzes the method of physical inventory currently employed by the WPMC Supply Activity, and explores whether more cost efficient methods are available.

Investigative Questions

1. What is the current method of physical inventories used by WPMC, and what are its associated costs, and impacts on customer service?
2. What cost and customer service criteria must be met before alternative methods of physical inventory may be considered?
3. What alternative methods of physical inventory, if any, are available?

4. What impact do physical inventory methodologies have upon the cost and customer service of the WPMC Supply Activity?

Scope and Limitations

This research focuses on the specific needs of the WPAFB Medical Center's Supply Activity and is limited to the situational constraints imposed by the new warehousing system. Alternative solutions considered for selection must meet or improve upon the current criteria established for cost and customer service parameters. If an alternative fails to meet or improve upon this criteria, then it will be discarded and not considered as viable.

This research begins with a review of the literature, with emphasis on physical inventory methods, costs, and customer service issues. Chapter III outlines the procedures used to collect and analyze the data to answer the investigative questions posed in this chapter. The results of the data analysis are discussed in Chapter IV. Finally, Chapter V summarizes the findings and recommendations that the data represents in relation to the physical inventory methodologies as they apply to the WPMC.

II. Literature Review

The following literature review describes and defines alternative physical inventory methods as they relate to the WPMC. In addition, the review presents potential strengths and weaknesses of those methods.

This chapter will begin by examining the purposes behind inventory management. Secondly, the automated storage system will be reviewed to develop an understanding of the environment in which the physical inventories must be conducted. Finally, to accomplish the established goals, the definitions and purposes of inventory and physical inventories will be examined, as well as the topics of customer service, inventory decay, and the costs associated with inventory and inventorying.

Following the establishment of specific terms and concepts associated with inventory management, three primary methods of physical inventories will be examined. They are the 100 percent fixed annual, statistical sampling, and cyclic inventories. These three categories of physical inventories were selected because they were the most common found in civilian industry and Department of Defense (DOD) organizations. The 100 percent fixed annual is probably the most commonly used method of inventorying. Its procedures are found in both civilian industry as well as the military. The physical inventory method of statistical sampling is

used in some civilian industry, and was requested to be included in the research by the Associate Administrator of Medical Logistics of the WPMC. For this research the cyclic method of conducting physical inventories is divided into two categories. They are the Continuous Cyclic (10 percent monthly) and the Stratified Cyclic. The Continuous Cyclic methodology is a process of taking 100 percent of the inventory on-hand, and then determining the number of lines associated with ten percent of that total. That number is then physically inventoried each month, which results in 120 percent physically inventoried during that cycle. The Continuous Cyclic method is an accepted procedure for physically inventorying within the DOD. Because of the similarity in the accounting systems, the Continuous Cyclic methodology appeared to be a valid alternative. The Stratified Cyclic methodology was discussed in different textbooks, and because of the nature of the problem (finding a less expensive method of physical inventorying without reducing customer service), it was considered by the researchers to be a viable alternative and worthy of consideration. This research will also analyze the impacts of the current standards of accuracy imposed by Air Force and DOD regulatory agencies, and the current methods of inventorying used at the WPMC. Finally, the research will review the impact of new warehousing procedures on the current WPMC inventory management system.

Inventory Management

Inventory management has historically been an intuitive requirement of merchants, retailers, and manufacturers. They needed to know how much material was required to meet the demands of their customers. They also needed to know when they would be required to reorder so that they could ensure that they always met their customers demands (Coyle, 1992: 217). Starr and Martin refer to this nature of inventory management and theory as a paradigm. The underpinning of the paradigm is the application of logic to meet business requirements (Starr, 1962: 3). According to Coyle and Bardi, the nature of supply management has become considerably more complicated in recent years. The supply managers must also be able to determine where the inventory should be held and the storage of specific lines in specific locations. Analytical tools such as computer software and automated equipment have been developed to assist supply managers in the prosecution of their duties (Coyle, 1992: 217). The WPMC has installed both computer software and an automated storage system within its supply activity to help in the management of its inventory.

Automated Storage System

The automated storage system the WPMC has installed is comprised of horizontal carousels, mobile aisles, and the

supporting software to operate the system. This section will describe the components of the WPMC's automated storage systems and their associated advantages and disadvantages.

Horizontal carousels are bins connected together in series which rotate around a vertical axis. The individual required to pick or count an item remains in a fixed location while the bins rotate to him or her. The primary advantage to using the horizontal carousel is it minimizes waiting times by having one worker control multiple carousels. The waiting time is minimized by the stock rotating to the worker, thereby alleviating the procedure of workers moving to or looking for a single item. Carousels working with appropriate software can establish the most efficient order in which multiple line items can be processed. (Coyle, 1992:402). The minimization of wait time can negate the problem of increasing physical inventory timelines as workers search for an item that is stored in multiple locations.

Mobile aisles are shelves or racks that are joined on a track, and they open allowing a picker or counter to gain access to the aisle. The advantage of the mobile aisle is that it facilitates high storage density. More shelves or racks are used because aisles do not need to be located between each shelf unit. The disadvantage with mobile aisles is the slower speed to access the aisle while the

warehouse worker waits for unwanted shelves to move out of the way (Coyle, 1992: 400).

The software system used to operate the storage system is called Material Handling Software (MHS) (Howard, 1994). The MHS controls all aspects of inventory in the warehouse. It performs those functions associated with material flow and inventory control. An advantage of MHS is that it performs all the same functions as the current Air Force support software for stock control of medical materiel (MEDLOG). The disadvantage is that the two software programs are not readily compatible, and therefore are performing redundant operations (Romeyn, 1994).

Inventory

The term inventory refers to those items that a company holds on-hand to support its operational needs. In his text, The Management of Business Logistics, Coyle defines inventory as, "The number of units and/or value of the stock of goods a company holds" (Coyle, 1992:564). Coyle states that the purpose of holding inventory or stocks is to "improve customer service", thereby ensuring that customers' demand for these items are met. In the case of WPMC, these items are in part demand supported or mission essential medical supplies that doctors and nurses need to provide quality health care to their patients. The items that the

administration section of the hospital uses are also considered inventory.

Physical Inventory

The term physical inventory refers to the process of counting inventory that is held by an organization to support its operational needs. Unlike inventory, which refers to the actual numbers of items held in stock, physical inventory is the process of counting those items held in stock. As shown in Chapter I, the Air Force requires its units to conduct physical inventories so the units can ensure that the stocks on-hand reflect the stock record's balance on-hand (DAF, 1990:12-4). The verification of stock records enables the inventory manager to effectively support customers by ensuring that the required number of items on-hand. Private medical institutions manage their inventories for similar purposes. W. Daniel Cobbs, the Director of Materiel Management at Mercy Hospital in Miami, Florida, concurs with the Air Force's reasoning when he states, "The first important reason to take a physical inventory is to measure how much of each item is actually in stock and compare that to how much the accounting department says is on-hand" (Cobbs, May 1981:49). Cobbs further adds, "It (inventorying) is also a means of evaluating the efficiency of materiel handling and inventory control of the organization" (Cobbs, 1981:49). Whether it

is a public or private medical institution, the primary reason for performing physical inventories is basically the same, and that is ensuring that the required materials are on-hand to support the customer.

Customer Service

In its purest sense, customer service is the ability of an organization to satisfy customer demands (Coyle, 1992: 197). The Logistics Manager for WPMC views customer service along two parameters: first, customer service is viewed as a function of inventory accuracy; second, customer service is viewed as a function of interruption of normal supply operations (Romeyn, 1994). Decreased inventory accuracy leads to decreased customer service levels through increased warehouse refusals (the warehouse is unable to issue due to unexpected stockouts). Normal supply operations are disrupted when a warehouse closes during the inventory period (DAF, 1990:12-4).

Inventory Decay

Inventory decay as defined by the researchers is the tendency for inventory to become imbalanced over time due to any number of different sources. Inventory decay contributes to the variation between on-hand and stock record balances. Variances between the actual on-hand balance and recorded balance do not magically appear. Items

within a warehouse do not relocate themselves. There are several possible reasons for these variances. Discounting pilferage, the most common errors occur when warehouse workers process transactions against an item of stock. Typically this means the issuing and/or receiving of inventory. According to one expert, these transactions affect the probability of an imbalance:

> A miscount here, lost paperwork there, misplaced parts in another case, and soon a number of variances have occurred. In automated systems these issue and receipt events are called inventory transactions; in fact inventory activity can be defined as the number of transactions against a given SKU (stockkeeping unit) per some time period. Any transaction has a probability α of causing a variance in the relevant SKU. (Neeley, 1987: 64)

Assuming the relationship between transaction and imbalances exists, immediately following a physical inventory the on-hand balance should match the recorded balance. After the first transaction against an item there exists a probability of α that the item is now an imbalance. All subsequent transactions will continue to decay the inventory accuracy. For example, after t transactions the probability of an item imbalance is α^t (Neeley, 1987: 64).

Cost of Inventory

When considering the quantity of items per line of inventory and the number of lines held in inventory,

managers need to be aware of costs associated with holding inventory. There are several costs associated with holding inventory on-hand. According to Coyle, the major costs associated with inventory are: carrying costs, order/set-up costs, and expected stockout costs (Coyle, 1992:200). For the purposes of this research, expected stockout cost is the most crucial. According to Coyle, expected stockout cost represents the cost of lost sales or production while the item is not available (Coyle, 1992: 205). For the WPMC environment, this may mean a delayed medical procedure or a loss of life.

Cost of Physical Inventory

The cost of conducting a physical inventory can be measured many different ways depending on the purposes of the inventory manager. However, for the purposes of this research, the cost of conducting a physical inventory includes the manpower costs associated with actually performing the physical inventory, and the costs associated with customer service. The cost of customer service is examined through determining inventory accuracy and warehouse downtime. Manpower costs are derived as a function of the number and respective pay grades of personnel who would actually perform the physical inventory. The resource management office at WPMC uses a matrix that projects manning requirements based upon each hospital

section's mission. It provides a breakout of personnel requirements by grade. By using this matrix the number of personnel required to perform a physical inventory and their pay grade can be derived and the cost per man-hour calculated.

Inventory Methodologies

The following examines the advantages and disadvantages of three physical inventory methods: 100 percent fixed annual, statistical sampling, and cyclic.

100 Percent Fixed Annual Physical Inventory. This method is one of the two methods currently approved for use by the Department of the Air Force. This method involves physically counting 100 percent of the stocks on-hand within a fixed time frame. The primary advantage of using the 100 percent is that the organization can verify at one time all of their actual stock on and against the stock record balances. According to Dobler, the 100 percent method works well in facilities where business is seasonal, or where the facility can close for a predetermined period of time (Dobler, 1987:476). However, where demand is constant this method may interfere with customer service, depending upon the time required to conduct the inventory. In his book, Production and Inventory Control, Plossl points out that 100 percent annual inventories often require that personnel

unfamiliar with the warehouse and with little training in inventory procedures be employed as counters. This, coupled with the fact that such personnel are under a time constraint, often results in a poorly executed inventory (Plossl, 1967:401). The 100 percent method is currently employed by the WPMC, and it results in a total shutdown of the warehouse for two weeks. During this time only high priority customer requisitions are processed (Romeyn, 1994).

Statistical Sampling. Statistical sampling is generally used by auditors to evaluate the effectiveness of an inventory control system. It is not recognized by the Department of the Air Force as an approved method of physical inventory. However, the Department of Defense (DOD) does recognize it as a method of evaluating overall inventory effectiveness at its Inventory Control Points (ICPs). This fact is illustrated by the following extract:

> A scheduled random statistical sample inventory of the total population of items in storage shall be conducted annually to determine the overall inventory accuracy, i.e., before research and corrective actions of each DOD Inventory Control Point (ICP). The purpose of this inventory is to assess the inventory process rather than the magnitude of the quantity and the dollar value of inventory adjustments. The results obtained from the scheduled random statistical sample inventory will enable management to measure improvements to the inventory process in a uniform manner. (DOD, 1987:4)

Statistical sampling, for purposes of this research, is closely associated with acceptance sampling. Acceptance

sampling is a method of quality control used to determine whether a lot (or population) meets a given criteria based upon a statistically determined random sample (Evans, 1993:212).

Statistical sampling's primary advantage over the 100 percent and cyclic inventory methodology is that it involves sampling just a portion of the population. As stated by Evans, in his text, The Management and Control of Quality, statistical sampling involves less time and money expended in collection of the sample versus the entire population (Evans, 1993:621). He further states that in "many cases, such as inspection, sampling may be more accurate than 100 percent inspection because of reduction of inspection errors" (Evans, 1993:621).

The disadvantage associated with statistical sampling can best be illustrated by the concept of risk, as it refers to statistics. As stated by Evans "in any sampling procedure one runs the risk of making an incorrect decision" (Evans, 1993:630). Sampling may be viewed as a statistical test of hypothesis: The null hypothesis is that the accuracy of the entire inventory meets or exceeds predetermined acceptance level, and the alternative hypothesis is that the entire inventory does not meet the predetermined acceptance level. According to Evans there are two types of errors associated with statistical inference:

> A Type I error refers to rejecting the null hypothesis when it is true, while a Type II error refers to accepting the null hypothesis when it is false. ... the probability of a Type I error - rejecting a lot of good quality - is commonly referred to as producer's risk. The probability of a Type II error - accepting a lot of poor quality - is called consumer's risk. (Evans, 1993:630)

For purposes of this research it follows that a Type I error, producer's risk, involves not accepting the accuracy of the inventory when in fact it is good. The Type II error, consumer's risk, is accepting the inventory accuracy as good when in fact it is not.

<u>**Cyclic Inventories**</u>. Cyclic counting is the second physical inventory method currently authorized by the Department of the Air Force. This method also involves counting 100 percent of the stocks on-hand. However, the counting is not performed all at one time. Dobler also refers to this method as a "continuous inventory" where a facility may divide its inventory into fifty-two equal groups and require one group be counted each week until they have all been counted one year later (Dobler, 1987: 476). There are several different methods of conducting cyclic inventories. One method, described by Plossl, involves stratifying the inventory and assigning varying inventory frequencies to the different strata, e.g. type "A" items will be counted three times each year, type "B" items will be counted twice each year, and type "C" items will be

counted every two years (Plossl, 1967:401). Plossl also describes a cyclic inventory method where items are only counted when they are reordered, which results in the faster moving stock being counted more often (Plossl, 1967,401).

The cyclic inventory method's primary advantage, according to Plossl, is that it allows the inventories to be conducted throughout the year, thus avoiding the costly shutdown of operations and the inevitable costs of overtime associated with 100 percent annual fixed inventories (Plossl, 1967, 401). Dobler points out the additional advantage of the relaxed manner in which a cyclic inventory may be conducted. Workers are given the time to conduct a thorough inventory at a pace which is less stressful (Dobler, 1987:476). Dobler goes on to point out that cyclic inventories also assist in the timely detection and elimination of basic causes of errors (Dobler, 1987: 476).

There are also disadvantages associated with the cyclic method. As Plossl points out:

> establishing paperwork cutoff dates (the dates after which no receipts or issues may be processed for the inventoried item) is difficult enough for annual physical inventory, but it becomes extremely challenging to handle effectively for cycle counts to be made while normal factory activity is going on. Picking up the paperwork in the system so that inventory can be properly reconciled to the records requires considerable ingenuity and discipline. (Plossl, 1967:401)

Chapter Summary

This chapter described and defined three alternative inventory methods and their potential strengths and weaknesses. This was accomplished by describing the purpose of inventory management and the automated storage system used by WPMC in order to facilitate an understanding of the environment in which physical inventories would be performed. Relevant terminology was examined to clarify the operational meanings of inventory, physical inventories, and their associated costs. Additionally, the researchers examined three different types of physical inventory methodologies. They were the 100 percent fixed annual, statistical sampling, and the cyclic. These three types of physical inventories were found to be the most common in civilian industry and the military. The remaining research will focus on the costs and customer service implications associated with performing these types of physical inventory. The next chapter will describe the methodology used to answer the research questions.

III. Methodology

Introduction

This chapter describes the procedures used to collect and analyze the data to answer the investigative questions posed in Chapter I. First, it explains the research design. Second, it depicts the means by which data was collected. Third, it defines how the data was manipulated. Finally, it describes how the data was analyzed.

Research Design

This section begins by examining the approach needed to effectively study the role of changing supply technologies on the WPMC Supply Activity. Second, it explains the development and justification of the investigative questions.

The case study approach was selected because it appeared to be the most appropriate method for the WPMC Supply Activity situation. Emory states that a case study approach is most suitable when it allows for the full contextual analysis of a limited number of events and their interrelationships (Emory, 1991:142). The researchers chose to study the interrelationship of a limited number of events which were physical inventory methodologies and the new warehousing technology. The researchers began by performing an empirical inquiry of the WPMC Supply Activity. Because

the boundaries imposed by the new warehousing technology at the supply activity were not clearly evident, the researcher needed a method of research that allowed for the investigation of the physical inventory phenomenon. According to Robert Yin a case study would be appropriate and he defines a case study as:

> ... an empirical inquiry that: investigates a contemporary phenomenon within its real life context; when the boundaries between the phenomenon and context are not clearly evident; and in which multiple sources of evidence are used. (Yin, 1989:23)

The research fits this interpretation of a case study because the need to examine the full context of the WPMC Supply Activity is the most important aspect. Yin also states that a case study is preferred when "a 'how or why' question is being asked about a contemporary set of events, over which the investigator has little or no control"(Yin, 1989:20). The question the researchers developed was: How will different physical inventory methods interact with the new warehouse technology, and what would the affect be on costs and customer service parameters? Both Emory's and Yin's definitions of a case study are satisfied by this research.

Each investigative question was developed in a sequential order to support the development of a full contextual analysis associated with a case study. The researchers first needed a baseline to compare differing

methodologies and understand how WPMC was currently performing its physical inventories. The literature review in Chapter II indicated that the 100 percent method is currently being employed at WPMC. The physical inventory costs and customer service parameters were also summarized in Chapter II, however the specific costs and customer service parameters are detailed in Chapter IV.

The next step in the research process was to determine what criteria an alternative had to meet to be considered as viable. Again, this criteria is centered around the cost and customer service parameters. The guidance given from WPMC was that they should match or improve upon the current physical inventory method.

Once screening criteria was established, different methodologies were evaluated. The literature review revealed four primary alternatives to be considered. They were the 100 Percent Annual, Statistical Sampling, Continuous Cyclic, and the Stratified Cyclic methods.

Once the differing physical inventory methodologies were derived, their impact upon the physical inventory cost and customer service parameters could be evaluated. The goal was to determine the best method of conducting physical inventories for WPMC. To accomplish this goal, common statistics for physical inventory cost and customer service parameters were developed to evaluate the alternatives.

First, the basis of the analysis for physical inventory cost was to evaluate man-hour cost per line. These costs were derived from historical documents, and a site survey (time study). The WPMC Supply Activity kept inventory records on-hand for two years. From these records, the number of lines inventoried were determined. The data from the historical record review was used to compute the number of line items inventoried for each man-hour. The site survey generated a statistic that represents the average man-hours required, to inventory, per item inventoried. By knowing the grades of the personnel who conducted the inventory, an average cost per man-hour could be calculated. The Air Force hospital resource management system uses a common algorithm to establish personnel strengths for the warehouse activity.

Once the man-hour cost per line item was derived, a matrix was developed to compare each of the alternatives with the original procedure. Manning requirements for each alternative vary, yet the common statistic can be applied and the cost derived. The common statistic provides the basis of comparison to determine the most cost efficient method of conducting a physical inventory for the WPMC.

Finally, the basis of the analysis of the customer service parameters was conducted. In the literature review, customer service parameters were broken down into two categories. They were inventory accuracy and operational

disruption. The parameter of inventory accuracy was addressed through development of a common error factor associated with an item. This error factor was then applied to the various physical inventory methodologies. A worst case loss was then derived for each of the methodologies. The procedures used to develop the worst case loss statistic is discussed in greater detail later in this chapter.

The parameter of operational disruption was evaluated using historical data for the 100 percent methodology and an extrapolation of time of disruption for the other methodologies using the man-hour data previously described.

This research was designed to facilitate an analysis of different physical inventory methodologies and how they would perform within the context of the WPMC Supply Activity. The researchers determined that the most suitable approach to performing this analysis was a case study. The research began by performing an empirical study of the WPMC Supply Activity and physical inventory methodologies currently employed in the supply industry. Comparative tools were then developed so that each physical inventory method could be evaluated. The method used to collect the data is explained in the next section.

Data Collection

Personal interviews were conducted to familiarize the researchers with the scope and context of the research

problem at the WPMC. The first interview was open ended, where questions were asked allowing the key respondent to impart his views and desires associated with the research. This initial interview was followed by a review of relevant literature and the development of follow on interviews that were more focused.

Archival records were also used for data collection. These included past inventory results which contain the number of line items inventoried, and the number and size of imbalances.

Observation was the last method used to collect data. A site survey was conducted to establish the man-hours required per line item to conduct an inventory.

Site Survey

The site survey data was obtained through an abbreviated time study. The time study consisted of selecting a sample of twelve counters, deemed by the Inventory Section Supervisor to be representative of those typically used for current inventories. The primary concern was to ensure various skill and knowledge levels were represented. The time to complete each count was monitored. The sample counts were conducted across a four day period. Three different counters were selected for each of the four days. The three counters were given a total of 36 randomly

selected line items to count. Each counter was supplied with a portion of the 36 lines to count.

The locations inventoried were broken down between the carousel (break bulk) and the movable aisle (bulk) storage areas. Two of the three counters were assigned to count the moveable aisle storage area while the remaining counter was assigned the carousel area. Each counter's time to complete the inventory was observed and recorded. The total time to complete was then calculated as well as an average time to count one line of inventory.

Manipulation of Data

The data for this research was obtained from historical sources and observation. The data was then manipulated to facilitate analysis and evaluation. Based upon the findings associated with the data collection, the parameters of concern are man-hour costs to conduct an inventory, and the customer service parameters of accuracy and operational disruption (warehouse downtime).

Man-hour costs per line item were derived by determining the manpower used as counters on the most recent inventory. The monthly base pay for these personnel was obtained from 1994 pay chart, and an average monthly pay for the counters was derived. The average monthly pay was calculated separately for civilians and military. The average civilian pay was calculated by first obtaining the

authorized grades from the WPMC's Resource Management office, and then by computing the average salary using the 1994 Salary Tables. For ease of computation the Step 1 column of the Salary Table was used. The military pay was calculated similarly by first obtaining the authorized grades, and then by averaging the associated salaries. For ease of calculation either the highest earning salary or the salary associated with twenty years of service was used. The purpose of the average salary is to allow for the use of a comparative tool for the differing methodologies. Using a standard monthly labor hours figure of 160 hours per month, an hourly labor cost was derived based upon a counter's average monthly pay. Using the average time to inventory one item from the site survey and then multiplying average time by the average hourly labor cost produced the man-hour cost per line.

The customer service parameter of inventory accuracy was based upon a projected worst case loss (WCL) metric. The WCL was derived to be a comparative metric of the worst case scenario for inventory imbalances based upon current imbalance rates. The WCL was based upon a review of previous inventory results and associated transaction history analysis. The Base Inventory Adjustment Document (PCN SI008-X04) provided a by line item summary of imbalances from the most recent 100 percent inventory on 23 May 1994 (See Appendix A). From the PCN SI008-X04, 173 line

items met the criteria established and were initially selected for analysis. The initial criteria for selection was lines with either a positive or negative imbalance that resulted in a financial loss of greater than $100.00 in inventory. Two lines were eventually eliminated as duplicates due to a key punch error at the time of the annual inventory. The Monthly Medical Material Transaction Registers (PCN SI008-Y24) were then manually reviewed to determine the number of receipt and issue transactions that processed against each of the remaining 171 lines over the previous 12 months (See Appendix B). A summary of the issue and receipt transaction codes that applied are in Appendix C. Seven lines which had no transactions were then removed from consideration. It was believed that these imbalances were due to either pilferage or an erroneous inventory in 1993. The result was 164 line items remained for further consideration.

Upon completion of the transaction register review an error factor for each item reviewed was derived using the following formula:

$$\text{Item Error Factor (IEF)} = \frac{\text{Number of Imbalances}}{\text{Number of Transactions}}$$

An average error factor (AEF) was then derived using the following formula:

$$AEF = \frac{\sum IEFs}{\text{Number of Lines Considered}}$$

The average number of transactions per line (AT/L) was then computed using the following formula:

$$AT / L = \frac{\sum Transactions}{\text{Number of Lines Considered}}$$

Finally, the Worst Case Loss Metric (WCL) was derived for each physical inventory methodology studied using the following formula:

$$WCL = \text{Lines Counted} \times AEF \times AT / L \times \text{Time Between Inventories}$$

The customer service parameter of operation disruption was based upon projected warehouse downtime due to physical inventories. To derive the metric which represents the period of operational disruption, two statistics were required. The statistics are time to count one item, and the number of items counted under each of the physical inventory methods.

The time to count one item was derived, as explained previously, using the method described in the site survey section of this chapter.

The number of items counted per physical inventory method statistic was different for each of the examined

physical inventory methodologies. The statistics for each methodology were derived as follows:

100 Percent Annual. The 100 percent annual physical inventory methodology, as its name implies, requires all of the inventory be counted as a single event. The number of lines to be counted was based upon the current total number of lines stocked by the WPMC at the time of this research.

Statistical Sampling. The number of lines inventoried, using statistical sampling, was derived using the Air Force Audit Agency's "STATS" program. The STATS program generated the sample size based upon an approximation of the binomial to a normal distribution (Vaden, 1994).

Continuous Cyclic. The 10 percent cyclic physical inventory methodology, as defined for this research, requires 10 percent of the inventory be counted each month. This results in 120 percent of the total inventory being sampled annually. The number of lines to be counted was based upon the current total number of lines stocked by the WPMC at the time of this research.

Stratified Cyclic. The number of lines inventoried using the stratified cyclic methodology was based upon a stratification of the total inventory population by the

number of receipt and issue transactions per line. By analyzing the Monthly Medical Material Transaction Registers (PCN SI008-Y24), the transaction history of the lines in the sample, as found in the PCN SI008-Y24, were summarized. The summary revealed the average number of transactions per line. This number was then used to derive the number of lines as a percentage of the sample that would be inventoried annually. If a line had more than the average number of transactions it would be inventoried once. If a line had more transactions than twice the average it would be inventoried twice. Similar criteria was applied to lines that had three or more times the average number of transactions. This percentage of lines that required inventorying was then applied to the population size and an annual physical inventory requirement was derived.

Analysis of Data

The data for this research was derived from the literature review process, historical data, and observation. This data was then transformed into qualitative information to facilitate analysis and evaluation. A three by four matrix was developed to facilitate the selection of a best alternative to compare to the current procedure (See Table 3.1 below). Raw data was initially used for comparative purposes and then converted to a rank score. Equal weight was given to all selection criteria. For all selection

criteria, the lowest dollar amount, WCL factor, or disruption time was considered best and given a ranking of one. The higher the raw data factor, the higher the ranked score. Ties in raw data were handled by taking an arithmetic average of the two ranked scores and posting the average to each alternative. The total of the rank scores for each alternative was used as the comparative metric.

		Customer Service	
	Cost	**Meets Accuracy Standard**	**Operations Disruption**
Alternative 1			
Alternative 2			
Alternative 3			
Alternative 4			

Table 3.1 Selection Matrix

The attribute of cost was separated from the other attributes so that a quantitative measure could be performed. The cost statistic of man-hour costs per line was used to determine the cost to conduct each inventory and form a basis for comparison. The customer service parameters provide a qualitative tool to evaluate the alternatives.

Because the sample size of this research is one (the WPMC), the methodology used to generalize and predict

manpower costs per line item would not be applicable Air Force wide. This is due to variation in inventory levels, stockage levels, and storage configurations which are driven by the mission requirements of each medical center in the Air Force. However, to predict Air Force-wide, a similar type analysis would need to be conducted at other medical centers throughout the Air Force system.

Chapter Summary

This chapter outlined the procedures used to research and answer the investigative questions. The methodology used to derive the costs and customer service parameters was the literature review. The case study method of research was used to determine the most cost efficient method of conducting physical inventories while providing a high level of customer service. The case study methodology allowed the researchers to examine the complete context of the inventory issue at the WPMC supply activity so that the purpose of this research could be achieved.

IV. Analysis and Results

Introduction

This chapter begins with an analysis of the data associated with each investigative question. The analysis consists of a summary of the information presented in the literature review for questions one through three. Next, investigative question number four is analyzed, and the calculations to estimate the common statistics used to compare the costs and customer service criteria of the different methodologies are presented. First, the cost to inventory a line item is derived. Secondly, the development of the statistics used to compare customer service levels are developed. Finally, a comparison of the physical inventory methodologies and their impact on the WPMC will be shown.

Investigative Questions

Investigative Question 1. **What is the current method of physical inventories used by WPMC and what are its associated costs and customer service parameters?**

As demonstrated in the literature review, the WPMC Supply Activity conducts a 100 percent annual physical inventory (Romeyn, 1994). The costs associated with a 100 percent annual physical inventory are calculated at $40,904.

The customer service parameter of inventory accuracy was calculated to be 31.8 units of stock lost within a 12 month time frame. The details of how these calculations were derived are explained later in this chapter. The supply activity historically has experienced a two week disruption of service to its customers while the physical inventory is conducted. The total operational disruption parameter was estimated at 80.3 hours. This disruption is in the form of limiting processing of requisitions to high priority requests only. The advent of the new warehousing technologies currently introduced may affect the time required to conduct the 100 percent annual physical inventory (Romeyn, 1994). The data collected during the site survey, to answer investigative question number four, indicates that this time will be reduced using the new warehousing technology. Currently, the WPMC Supply Activity is experiencing a 89.5 percent accuracy rate for the 3979 lines of inventory (Kras, 1994).

Investigative Question 2. **What cost and customer service criteria must be met before alternative methods of physical inventory may be considered?**

The literature review process revealed that manpower costs, inventory accuracy, and operational disruption times were the criteria to be used in evaluating different physical inventory methods. Alternative physical inventory

methodologies must also demonstrate an equal or lower cost than the current 100 percent annual system, to be considered competitive (Romeyn, 1994). The cost statistic to conduct the comparison is addressed in the Inventory Cost section of this chapter.

In addition, alternative physical inventory methodologies must meet or exceed the current methodology's customer service parameters to be considered competitive. A description of customer service parameters are described in the literature review and the analysis of the applied statistics is discussed later in the Customer Service section of this chapter.

Investigative Question 3. **What alternative methods of physical inventory, if any, are available?**

Based upon the information presented in the literature review, there are currently three primary acceptable methods of physical inventorying. The three primary methods are 100 percent annual, statistical sampling, and cyclic physical inventories. The cyclic physical inventory method may be subclassified as continuous or stratified. For the purposes of the WPMC Supply Activity, the continuous method is defined as a 10 percent monthly, and the stratified method is driven by transaction history.

Investigative Question 4. **What impact do physical inventory methodologies have upon the cost and customer service of the WPMC Supply Activity?**

An analysis was conducted of each methodology using common statistics for cost and customer service as outlined in Chapter III. The physical inventory methodologies selected as a result of the literature review were 100 percent annual, statistical sampling, continuous cyclic (10 percent monthly), and stratified cyclic (transaction driven). The level of stratification was selected to illustrate the mean number of transactions.

Inventory Cost. As shown in the literature review, the primary cost factor associated with the physical inventory process at the WPMC Supply Activity is manpower cost. Manpower costs were estimated using a time study to acquire an average cost per man-hour per line item.

Twelve different personnel were used to conduct a physical inventory time study. The warehouse manager randomly selected twelve individuals considered as a cross section of the personnel commonly used during the inventory. There was no historical data to reflect exactly which personnel were previously used to conduct physical inventories. The selected physical inventory personnel consisted of 41.67 percent warehouse personnel familiar with the warehouse environment and the MHS system. 58.33 percent

of the sample were non warehouse personnel with only rudimentary knowledge of the warehouse environment and the MHS system.

Based upon the results of the time study, it was found that of the 140 lines sampled, an average of 1.212 minutes per line were required to inventory (See Table 4.1).

To determine the average cost per man-hour, the Air Force Manpower Standard 5110 was used. From the manpower standards the number and grade of the personnel available to conduct physical inventories was derived. The number and grade was then cross referenced to the civilian and military pay scales to determine an average cost for the required personnel. For the civilian pay scale the General Schedule at step 1 was used to provide a common statistic as a comparative tool. The average hourly civilian rate is $9.68. For the military pay a similar approach is used by taking a set time-in-service level per grade to develop the comparative statistic. The average hourly military rate is 10.88. The average combined hourly rate for both military and civilian pay is 10.28. The hourly pay is based upon 160 hours per month.

With the estimated time to count one line of inventory and the cost per man hour established, the number of lines to inventory per physical inventory method must be determined. The number of lines per method is estimated using the following methods (summary at Table 4.3):

		RAW TIME		DECIMAL
RANK	DUTY POSITION	CAROUSEL	BULK	TIME
Airman Basic	Warehouse	N/A	10:28	10.4667
Airman	Warehouse	18:00	N/A	18.00
Airman First Class	Cust Svc	N/A	18:45	18.75
Airman First Class	Requisitions	9:05	N/A	9.08334
Airman First Class	Acquisitions	N/A	13:08	13.13334
Staff Sergeant	Warehouse	N/A	10:03	10.05
Staff Sergeant	Acquisitions	N/A	13:30	13.50
Staff Sergeant	Requisitions	N/A	13:07	13.11667
Staff Sergeant	Acquisitions	12:20	N/A	12.33334
Master Sergeant	Acquisitions	N/A	15:55	15.91667
Civilian	Warehouse	17:50	N/A	17.83334
Civilian	Warehouse	N/A	17:32	17.53334
Total Inventory Time (min)				169.7167
Average Time to Count an item (140 Line Items) (hrs)				.0202

Table 4.1 Physical Inventory Time Study Results

1. 100 Percent Annual Method, the current number of lines on hand is used. Currently there are 3979 lines on hand.

2. Statistical Sampling, the sample size was derived using the Air Force Audit Agency's "STATS" program. The stats program generated the sample size based upon an approximation of the binomial distribution. A historical accuracy rate of 89.5 percent was used as the base line for the computation. The population size was given as 3979 lines, and a 95 percent required confidence level was used. This resulted in a sample size of 139 lines inventoried once annually.

3. Continuous Cyclic (10 percent per month), the annual inventory quantity was estimated to be 120 percent of the current number of lines on hand. This resulted in 4774.8 lines inventoried annually.

4. Stratified Cyclic, the annual inventory quantity was estimated using the mean number of transactions (42.981 transactions). Utilizing the sample of imbalances and transactions drawn from the most recent inventory (April 1994) an analysis was conducted. The analysis revealed that, if items were inventoried every 43 transactions, the 164 lines in the sample would undergo 98 separate physical inventories. The number of inventories represents 59 line items being inventoried. Of the 59 line items inventoried 24 would require a

second physical inventory, 12 would require a third physical inventory and three would require a fourth inventory. Using straight percentages from the sample applied to the population of 3979 line items, 2389 line item physical inventories would be required (see Table 4.2).

Sample		Population
No of Inventories	Percent of Sample	No of Inventories
1	59/164 = 36%	1433
2	24/164 = 15%	597
3	12/164 = 7%	279
4	3/164 = 2%	80
	TOTAL	2389

Table 4.2 Estimation of Number of Physical Inventories

Method	Number of Lines to Inventory Annually
100%	3979
Statistic	139
10% Cyclic	4775
Stratified Cyclic	2389

Table 4.3 Summary of Annual Inventory Requirements

Once, the man-hour cost per line item and the number of lines per method was determined, the total direct labor cost associated with each method was computed by multiplying the two calculations together. Table 4.4 reflects the predicted cost to physically inventory the on hand stock at the WPMC Supply Activity by method.

Inv Method	**Cost/Line**	**Number of line inventories**	**Total Cost**
100%	10.28	3979	$40,904
Statistic	10.28	139	$1,429
10% Cyclic	10.28	4774.8	$49,085
Stratified Cyclic	10.28	2389	$24,559

Table 4.4 Inventory Cost Summary

Customer Service Parameters. Based upon personal interviews summarized in the literature review it was determined that the primary concern of the Logistics Manager for WPMC was to maintain inventory accuracy and minimize the disruption of warehouse operations. These parameters were viewed as being elements of customer service by the WPMC Logistics Manager. The following sections represent the derivation of common statistics which were used to measure

the customer service parameters of inventory accuracy and operation disruption.

Inventory Accuracy. Inventory accuracy is represented by the Worst Case Loss Error Factor (WCL), the derivation of which is detailed in Chapter III. The WCL represents the maximum expected loss for an individual line given an error factor based upon historical transactions. The literature review revealed that the primary cause for inventory imbalances was due to receipt and issue errors. Given this fact, results of the most recent 100 percent annual inventory were reviewed. Line items which were in an imbalance status at that time were selected to derive the Average Error Factor (AEF). The sample size was limited by selecting only those lines whose total value of imbalance exceeded $100.00, the amount which is non-reportable per current Air Force Regulation (DAF, 1990:12-4). The sample size was further limited to those lines that had transactions against them during the previous year. This resulted in a sample size of 164 line items. Of the lines sampled there was an average of 42.7195 transactions per line, since the last annual physical inventory. The resulting AEF was .744467, as depicted in Table 4.5 and Appendix C.

	Lines Sampled	Item Error Factors
Total	164	122.0926
		AEF = 0.744467

Table 4.5 Average Error Factor Summary

The AEF was then applied to the various physical inventory methodologies and the WCL was computed. The determination of the WCL factor for each physical inventory methodology is discussed below, and a summary of all factors are at Table 4.6.

1. The 100 Percent Annual Method, as its name implies, has a time between inventories of 12 months. The AEF and AT/L were computed previously. The resulting WCL was 31.80328 units of stock.
2. Statistical sampling represents a unique challenge when evaluating WCL. In theory an item may never be selected for a physical inventory given a truly random sample. An arbitrary time frame of five years was selected as the time between physical inventories. The AEF and the AT/L were the same as used in the 100 percent annual method. The resulting WCL was 159.0164 units.
3. The continuous (10 percent cyclic) method required that 100 percent of the inventory be counted in ten months. This resulted in a time frame of .834

years between inventories. The AEF and the AT/L were the same as the 100 percent annual and the statistical sampling methods. The resulting WCL was 26.52394 units.

4. The stratified cyclic does not use a time factor as a basis for inventories. Therefore, time between inventories is dependent upon the number of transactions that process against a line. The determination of the optimal number of transactions that must process before a count should be initiated was outside of the scope of this research. Therefore, the average number of transactions was selected as optimal, as it had resulted in an inventory accuracy of approximately 90 percent on the most recent 100 percent annual inventory. The AEF was the same as that employed in calculating the WCL for the other physical inventory methodologies. The resulting WCL for the stratified cyclic method was 31.80328 units. This WCL was exactly the same as that of the 100 percent annual method. This result was expected based upon the method in which the WCL was computed.

Method	Time Between Phys. Inv.	Avg. Error Factor (AEF)	Avg. Number of Trans. (AT/L)	Worst Case Loss (WCL)
100%	1 Yr	.744467	42.7195	31.80328
Statistic	5 Yrs	.744467	42.7195	159.0164
10% Cyclic	.834 Yr	.744467	42.7195	26.52394
Stratified Cyclic	N/A	.744467	42.7195	31.80328

Table 4.6 Worst Case Loss Summary

Operational Disruption. The operational disruption metric is based upon projected warehouse downtime due to physical inventories. Two statistics were required to derive this metric for each of the physical inventory methodologies. The statistics are time to count one item and the number of items counted annually.

The time to count statistic is the same for all physical inventory methods. It was derived from the site survey (time study), and was determined to be 1.212 minutes per item.

The statistic representing the number of items to be counted annually varies among physical inventory methodologies. The statistic was derived as described in

the man-hour cost summary section. The number of items to be inventoried annually is summarized at Table 4.3.

The product of the time to count one item and the number of items counted produced a total operational disruption statistic for each physical inventory methodology, and those products are depicted in Table 4.7.

Methodology	Time to Count One Item (Min)	Number of Items to be Counted	Total Operational Disruption (Min / Hrs)
100%	1.212	3979	4822.5 / 80.3
Statistic	1.212	139	168.5 / 2.8
10% Cyclic	1.212	4775	5787.3 / 96.55
Stratified Cyclic	1.212	2389	2895.5 / 48.3

Table 4.7 Operational Disruption Summary

Impact Comparison

After determining the statistics for the parameters of cost and customer service, a comparison of the selected physical inventory methodologies was conducted. The comparison was accomplished using the three by four matrix described in Chapter III. The raw data is presented in Table 4.8.

		Customer Service	
	Cost	Inventory Accuracy	Operations Disruption (Hrs)
100%	$40,904	31.80328	80.3
Statistic	$1,429	159.0164	2.8
10% Cyclic	$49,085	26.52394	96.55
Stratified Cyclic	$24,559	31.80328	48.3

Table 4.8 Selection Matrix (Raw Data)

The data was then converted to a rank order scoring, as described in Chapter III, and presented in Table 4.9. The total score of the ranks, for each alternative, was used as the comparative value.

		Customer Service	
	Cost	Inventory Accuracy	Operations Disruption
100%	3	2.5	3
Statistic	1	4	1
10% Cyclic	4	1	4
Stratified Cyclic	2	2.5	2

Table 4.9 Selection Matrix (Rank Score)

Chapter Summary

This chapter presented the analysis of the data collected during the research process and the associated results using the methodology described in Chapter III. In determining the best alternative methodology for the WPMC, the researchers answered each investigative question in sequence. The impact of each methodology was assessed in response to investigative question four. This impact assessment indicated the best and worst methodologies based upon cost, inventory accuracy, and operational downtime. By using the three by four matrix the researchers were able to reach specific conclusions and make recommendations that are presented in Chapter V.

V. Findings and Recommendations

Introduction

Current trends toward more efficient and effective inventory management within the DOD are causing many changes in the way supply business is conducted. The preceding chapters of this research have dealt with establishing a basic understanding of physical inventory methodologies, collection, and analysis of data. This chapter provides the researcher's findings and recommendations.

Findings

This research lists each physical inventory methodology and analyzes it in terms of cost criteria and customer service parameters as presented in Table 4.8 of the preceding chapter.

100 Percent Fixed Annual. The main advantage to performing this type of physical inventory is the relatively high rating it receives under the customer service parameter of inventory accuracy.

The disadvantages of this methodology are the high inventory cost and amount of time that operations are disrupted. Historically, the time to conduct a physical inventory is approximately two weeks. However, a 100 percent physical inventory has not been conducted in the new

facility, therefore a time to count can only be estimated. Physically inventorying the complete warehouse would cost more than inventorying a lesser portion of the warehouse. However, this cost is a serious drawback, and is one of the primary reasons that this research was initiated. Additionally, not only are man-hour costs incurred, but also a loss of goodwill with customers occurs because of the disruption of operations.

Statistical Sampling. The advantages associated with Statistical Sampling are the low cost to inventory, and the minimal disruption of normal operations in the warehouse. The low cost is realized because of the few lines required to be physically inventoried annually. Due to the relatively small sample size, the operational disruption is minimal.

The disadvantage of Statistical Sampling is the high WCL factor associated with making a Type II error, consumer's risk, by accepting the inventory accuracy as being good when, in fact, it is not. This consumer's risk could result in increased stockouts. Additional research is needed to fully ascertain the impact of compounded errors over an extended time frame. With advanced warehousing and computer technologies, errors could potentially be controlled. If errors can be controlled, then statistical

sampling may not incur the high inventory accuracy penalties as indicated in this research.

<u>Continuous Cyclic (10 Percent Monthly)</u>. The advantage of this methodology was the high level of inventory accuracy. This greater level of inventory accuracy results from 120 percent of the inventory being counted annually.

The main disadvantage associated with this methodology is the cost to physically inventory 120 percent of the stocks on-hand. The operational downtime is greater than that of the 100 percent annual. However, because the downtime is distributed throughout the year, the customer would not realize any serious disruption in service. The disadvantage of cost and operational disruption could be lessened to the point of equaling that of the 100 percent annual by simply changing the monthly percentage inventoried to equal 100 percent annually. This would have the added advantage of distributing the operational downtime over a twelve month time frame.

<u>Stratified Cyclic</u>. The research has failed to indicate any significant disadvantages associated with the Stratified Cyclic methodology. Because this methodology focuses on the lines with potential for error, based upon error producing transactions, manpower and time are not expended on inventory that has not been exposed to the risk

of error. This effort results in lower costs and less operational disruption while simultaneously maintaining inventory accuracy. Additional research is necessary to establish the corollary between inventory accuracy, transaction density, and other parameters yet to be determined. Research is also needed to determine the optimal transaction density for a given inventory accuracy rate.

Recommendations

Based upon the criteria of inventory cost alone, the Statistical Sampling methodology proved to be the most economical. However, the disadvantages associated with potentially high inventory inaccuracy rate make it a less attractive alternative. The Stratified Cyclic method appears to have less extreme scores in both the cost and customer service parameters. Generally, this study indicates that the WPMC Supply Activity should continue research in the areas of Statistical Sampling and Stratified Cyclic physical inventory methodologies because they received the lowest overall total scores in Table 4.9. To facilitate the follow on research, test beds should be established within different FSCs to analyze the impact of the recommended methodologies. If the disadvantages associated with the Statistical Sampling methodology can be eliminated, reduced or disproved, then it should be adopted

for the entire warehouse. If the disadvantages of the Statistical Sampling methodology persist, then some form of Stratified Cyclic should be adopted.

Recommendations for Further Study

This research has made no attempt to cover all areas of study that must be considered prior to full implementation of a specific physical inventory methodology. Some areas were specifically excluded to limit the scope of the study.

The study deliberately included physical inventory methodologies presently not authorized by the DOD. Currently, the two authorized methods of conducting physical inventories are 100 percent annual and the continuous cyclic, both of which result in 100 percent of the inventory being counted annually (DAF, 1990:12-4). The inclusion of non-authorized methods was done to encourage further research with the goal of reducing costs while maintaining or improving customer service levels.

Based upon the conclusions of this research recommendations for further research are listed as follows:

1. What impact does the automated storage system have upon inventory accuracy at the WPMC Supply Activity?

2. Can a strong correlation be established between transaction density and imbalance rates, within the WPMC Supply Activity?

3. What additional factors, besides transaction density, help to predict imbalance rates, within the WPMC Supply Activity?

4. Can an optimal transaction density rate be determined for a given accuracy rate at the WPMC Supply Activity?

5. What is the actual effect of a statistical sampling plan upon inventory accuracy at the WPMC Supply Activity?

Further research in these areas will serve to validate the potential for cost savings within the WPMC Supply Activity. These potential savings could impact the entire DOD supply system. When viewed on such a large scale the potential overall savings to the taxpayer is significant.

Appendix A: Base Inventory Adjustment Document (PCN SI008-X04)

PREPARED 93 JUN 30 BASE INVENTORY ADJUSTMENT DOCUMENT AS OF 93 JUN 30 PCN SI008-X04

FN5690 DETACHMENT B JULIAN DATE 93181

STOCK NUMBER	ITEM IDENTIFICATION	INV CODE	E X	NM AC	U/I	UNIT PRICE	OVERAGE QTY	OVERAGE $ VALUE	SHORTAGE QTY	SHORTAGE $ VALUE	TRANS CODE	DOCUMENT DATE SER#
5305009265590	SCREW INST SPEC 100OS	A1	1		SE	22.50	2	45.00			IAG	31816502
6510005977469	BANDAGE ADH 3-4X3IN 100S	A1	1		BX	.91			10	9.10	IAL	31816502
						TOTAL	2		10			

CERTIFYING OFFICIAL ______________ DATE ________ APPROVING AUTHORITY ______________ DATE ________

(DAF, 1993:12-28)

Appendix B: Monthly Medical Material Transaction Registers (PCN SI008-Y24)

```
PREPARED 93 JUN 30                               MONTHLY MEDICAL MATERIEL          AS OF 93 JUN 30   PCN SI008-Y24
FM5690                                            TRANSACTION REGISTER                                  JULIAN DATE 93181

STOCK NUMBER    D ITEM IDENTIFICATION        E F FU U/I RID PS     UNIT     U P D NC  LOC  N CN CI DP              TRANSACTION
                I                            X T ND          &M    PRICE    C S C     CODE C CD CD CD              DATE/SEQ #

D R RC/CC RV DOCUMENT MM E INV TRN EXP  <           O P E R A T I N G                        ><       W R M              >
T F       CD NUMBER   AC I CDE CDE DATE < D/I   D/O  SERV  LEVEL    EXCESS   PROJ   RP/SU  ><   D/I  SERV  LEVEL  RP/SU >

6505000631484      SODIUM CHLORIDE 25 LB    1 N 6B EAB S9M CO      1.17    S                                            93152
               OPENING BALANCE LINE          6                14                                                       93152
A R          30981000 CG     1  RRD 9212     6-         6                                                              162001
A R          30981000 CG     1  RMD 9212                6                                                              162002
6505000631484      SODIUM CHLORIDE 25 LB    1 N 6B EAB S9M CO      1.17    S                                            93181
               TOTAL CLOSE BALANCE                     12     14                                                       93181

6510002004000      BAND GAUZE RL 2INX5YD12  1 N 6B PG  S9M CO      4.07                                                 93152
               OPENING BALANCE LINE                                                                36     36           93152
A R          31651035 AA    SA  ESD                                                          50                        165001
A                           SA  SLR                                                                       150          165002
A            31727349       SA  SFG                                                                50                  172001
A               CLOSE PROJ  MA                                                                     36     36           93181
A               CLOSE PROJ  SA                                                                     50     150          93181
6510002004000      BAND GAUZE RL 2INX5YD12  1 N 6B PG  S9M CO      4.07                                                 93181
               TOTAL CLOSE BALANCE                                                           50    86     186          93181

P4516002011        NO OPENING MASTER
                   NO OPENING BALANCE
P4516002011      FROM NSN  P0040010004                                                                                 162001
             31626515       1  SPZ                                                                                     93181
P4516002011        BRACKET                  1 N 6B EA  S9M CA     14.00  U                                              93181
                   TOTAL CLOSE BALANCE                  6      6
```

(DAF, 1993:24-56)

Appendix C: Transaction Codes That Affect Physical Balances in MEDLOG

Receipt Transaction Codes (Add to balance)

- RRD - Receipt of an item Due-in
- RND - Receipt of an item Not Due-in
- SDG - Shipping Discrepancy Gain
- RXD - Receipt of Excess Material

Issue Transaction Codes (Subtract from balance)

- NRI - Non-Recurring Issue
- BRI - Back Order Release
- SGI - Shopping Guide Issue
- EMI - Emergency Issue
- PII - Post Issue
- SDL - Shipping Discrepancy Loss

Other Transaction Codes

- DDL - Destruction
- DNL - Destruction (Authorized by higher authority)
- SFL - Stock Fund Loss
- SFG - Stock Fund Gain
- TIG - Turn-in Gain
- IAG - Inventory Adjustment Gain
- IAL - Inventory Adjustment Loss
- TZL - Transfer to DRMO
- RVL - Loss because of return to Vendor
- RXL - Loss because of return to Depot
- DPG - Donated Property Gain
- FBG - Found on Base Gain
- FCG - Receipt from DRMO

(DAF, 1993:24-12)

Appendix D: AEF Summary

IMBAL	TRANS	IEF
1	10	0.1
21	7	3
13	47	0.277
12	15	0.8
10	11	0.909
292	168	1.738
2	1	2
8	72	0.111
20	32	0.625
13	138	0.094
12	73	0.164
3	34	0.088
3	67	0.045
17	115	0.148
24	76	0.316
2	31	0.065
4	61	0.066
4	52	0.077
1	48	0.021
11	11	1
2	6	0.333
5	31	0.161
2	76	0.026
60	131	0.458
32	57	0.561
10	39	0.256
3	48	0.063
72	127	0.567
4	17	0.235
6	2	3
39	74	0.527
1	9	0.111
8	17	0.471

IMBAL	TRANS	IEF
5	42	0.119
24	90	0.267
4	5	0.8
2	19	0.105
11	60	0.183
12	168	0.071
1	21	0.048
123	197	0.624
2	98	0.02
1	32	0.031
2	3	0.667
1	84	0.012
8	76	0.105
92	159	0.579
3	51	0.059
11	2	5.5
1	60	0.017
6	102	0.059
8	122	0.066
134	155	0.865
1	114	0.009
2	88	0.023
6	71	0.085
21	188	0.112
1	13	0.077
6	155	0.039
27	34	0.794
4	32	0.125
2	1	2
1	11	0.091
1	26	0.038
5	159	0.031
2	11	0.182

IMBAL	TRANS	IEF
1	23	0.043
1	29	0.034
4	3	1.333
2	6	0.333
46	127	0.362
2	15	0.133
7	15	0.467
4	4	1
4	2	2
235	102	2.304
9	11	0.818
2	183	0.011
14	52	0.269
17	117	0.145
20	1	20
2	21	0.095
9	75	0.12
10	80	0.125
1	6	0.167
29	56	0.518
3	14	0.214
10	29	0.345
3	21	0.143
5	17	0.294
2	39	0.051
44	45	0.978
5	6	0.833
7	15	0.467
8	87	0.092
10	57	0.175
2	1	2
1	48	0.021
2	42	0.048

IMBAL	TRANS	IEF
1	5	0.2
4	27	0.148
1	17	0.059
15	5	3
4	74	0.054
7	10	0.7
15	3	5
2	23	0.087
4	55	0.073
1	21	0.048
18	4	4.5
1	6	0.167
1	23	0.043
2	39	0.051
4	40	0.1
2	46	0.043
3	5	0.6
6	3	2
5	17	0.294
2	8	0.25
3	18	0.167
8	45	0.178
1	24	0.042
2	4	0.5
1	3	0.333
12	13	0.923
1	1	1
1	5	0.2
60	16	3.75
1	3	0.333
10	2	5
22	9	2.444
8	2	4

IMBAL	TRANS	IEF
1	21	0.048
2	13	0.154
4	49	0.082
26	69	0.377
4	23	0.174
11	2	5.5
9	72	0.125
4	4	1
2	58	0.034
1	6	0.167
1	4	0.25
11	101	0.109
1	11	0.091
4	42	0.095
9	24	0.375
1	2	0.5
70	140	0.5
1	36	0.028
1	6	0.167
7	16	0.438
2	11	0.182
7	35	0.2
33	23	1.435
5	19	0.263
2	7	0.286
2	13	0.154
11	40	0.275
17	5	3.4
3	8	0.375
13	21	0.619
12	48	0.25
TOTAL	7006	122.1
AVG	43	0.744

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Vita

Captain Steven M. Elkins was born 2 March 1960 in Houston, Texas. He graduated from Western Heights High School in Oklahoma City, Oklahoma in 1978. In January 1979 he enlisted in the United States Army as a Nuclear Weapons Maintenance Specialist. After achieving the rank of Sergeant, he was selected for direct appointment as a Warrant Officer in May 1982. In December 1985, he completed Officer Candidate School and was commissioned into the Ordnance Corps. While assigned to Redstone Arsenal, Alabama, Captain Elkins attended Athens State College in Athens, Alabama, and graduated in March of 1988 with a Bachelor of Science Degree in Business Administration. Captain Elkins has served in a variety of ammunition and maintenance assignments which culminated with his taking command of the 563rd Ordnance Company (missile maintenance) at Wiesbaden, Germany in September 1991. Upon completion of his command assignment in May 1993, he entered the School of Logistics and Acquisition Management, Air Force Institute of Technology.

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Vita

Captain Scott A. Parks was born on 22 March 1962 in Bemidji, Minnesota. He graduated from Bemidji High School in Bemidji, Minnesota in 1980 and attended Bemidji State University, graduating with a Bachelor of Science Degree in Industrial Technology in March 1986. Upon graduation he received a Regular Army commission and served his first tour of duty with the 229th Supply and Service Company, in Augsburg, Germany, as a Platoon Leader. He then attended the Quartermaster Officer Advance Course and the Petroleum Officer Course at Fort Lee, Virginia, in 1990. His next assignment was with the 10th Mountain Division (Light Infantry) as the S-2/3 (Operations Officer) for the 46th Forward Support Battalion and Commander, Headquarters and Headquarters Company, 10th Division Support Command. During his command, his unit deployed in support of Joint Task Force Andrew (Florida) and Operation Restore Hope (Somalia). Upon completion of his command assignment (May 1993), he entered the School of Logistics and Acquisition Management, Air Force Institute of Technology.

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13. ABSTRACT *(Maximum 200 words)*
This study evaluates current and alternative physical inventory methodologies for the Wright-Patterson Medical Center Supply Activity. Four potential physical inventory alternatives were examined: 1) 100 percent annual physical inventory; 2) statistical sampling, 3) continuous cyclic; and 4) stratified cyclic. For each alternative the researchers used historical data and a site survey to estimate the effect on physical inventory costs and impact on customer service. The researchers found that statistical sampling was the most economically feasible alternative for the Wright-Patterson Medical Center. However, the method of stratified cyclic produced less extreme scores in both physical inventory cost and customer service parameters than did statistical sampling. The researchers found that further research is needed in the recommended methodologies of statistical sampling and stratified cyclic.

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